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ABSTRACT

The general objectives of an Arkansas technical school's self-paced individualized instruction program were designing, field testing, and disseminating an instructional management system with support materials that identify and justify the need for a program of instruction. Eight specific objectives have been developed to facilitate students' learning patterns: (1) students are enrolled at regular intervals; (2) a variety of teaching methods and instructional materials encourage self-paced learning; (3) task analysis exercises are based upon performance criteria; (4) performance guides contain knowledge that is prerequisite to skill performance; (5) the instructional materials, equipment, knowledge, skills, and attitudes necessary for task completion and mastery are identified; (6) management system tracks all students through the program; and (7) evaluation ensures occupational competence for terminating students. (The document contains a project description, student evaluation instrument, competency record, course syllabus, and course outline. A Learning Activities Packet (LAP) overview for electricity concepts I and II and a LAP for electricity concept--Ohms Law--are included. The LAP includes performance objectives, tasks, learning steps, unit and specific objectives, an information sheet, assignment sheets and answers, and a job sheet.) (NLA)

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FINAL REPORT

PROJECT FOR PROGRAM IMPROVEMENT THROUGH THE UTILIZATION OF SELF-PACED INDIVIDUALIZED INSTRUCTION CONCEPTS INDUSTRIAL EQUIPMENT TECHNOLOGY

Conducted by
Crowley's Ridge Vocational Technical School
Forrest City, Arkansas
Burl W. Lieblong, Project Director

In Cooperation with
Vocational and Technical Education Division
Arkansas Department of Education
Little Rock, Arkansas 72201

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INTRODUCTION

Having many students enrolling at different times during the school year, Crowley's Ridge Vocational Technical School needed a self-paced individualized instruction program. The open-entry open-exit program as it now eists in vocational education does not adequately meet the training needs of all the students. In many cases when a student enrolls, he is required to play catch-up in a lock-step curriculum system. In the majority of programs, students are forced to move at the same pace — traditional classroom situation.

In the traditional classroom situation, the more gifted students are often bored when the training program does not move forward as rapidly as they learn and develop skills. At the same time the lower level students are frustrated at their inability to move through the material and assignments as rapidly as they are rec .ed to in order to keep up with their peers. Drop-out is sometimes higher than desired.

Due to these findings, the school's administration felt that something was needed to strengthen the instructional program to benefit each student and motivate each student to stay and continue his/her education and training. Thus the self-pace program was the answer to the two-fold problem of open-entry open-exit program and the answer to each student moving at his "best" pace. Each student should be allowed to go ahead in different subjects as rapidly as they can.

OBJECTIVES

The overall objectives of the self-paced individualized instruction concepts include designing, field testing, and disseminating an instructional management system with support materials that would identify and justify the need for a self-paced individualized program of instruction in the Industrial Equipment Technology Department at Crowley's Ridge Vocational Technical School.

The main objective of this project was to design a self-paced individualized instruction program that will allow the students to work with material best suited to their aptitudes and abilities. The scope of the program was to find materials which would facilitate an individual student's learning pattern.

The following include the specific objectives as they relate to the self-paced individualized instruction program.

1. Design a program which will allow students to enroll at regular intervals and remain until they have acquired the necessary competencies for entry level employment.
2. Develop a curriculum design which will include a variety of teaching methods and instructional materials designed to facilitate the individual learning patterns of students.
3. Develop task analysis/validation exercises based upon performance criteria.
4. Develop performance guides containing knowledge that is pre-requisite to skill performance.
5. Identify the knowledge, skills, and attitudes necessary for each student to master the task.
6. Develop learning activities which will identify student activities required to complete each task.

7. Develop or identify instructional materials and equipment needed to complete a task.
8. Develop a management system to track all students through the program.
9. Develop evaluation documents that will assure occupational competence for students terminating from the program.

By allowing students to progress through self-paced individualized programs with learning activities geared toward individual aptitudes and abilities, students know exactly what is expected of them and quite possibly become motivated to progress beyond the scope of the unit as their interests lead them.

PROCEDURE

In October, 1987, the school began the program by hiring a self-pace coordinator to initiate the planning, developing, and implementation of the program at Crowley's Ridge Vocational Technical School. This individual was given the responsibility of coordinating all phases of the self-pace program.

An advisory committee was established to assist in the planning and the implemantation activities. This committee played a vital role in being a resource committee.

The coordinator worked with the instructor in outlining the sequence of instruction, identifying each unit of instruction and the corresponding general and specific performance objectives. Other areas of research were conducted: an inventory of materials on hand was made; a search for additional self-pace concepts material for each unit of instruction was made; contacts and frequent visits with specialist in the field were made; visits to other vocational technical schools were made; workshop participation was done.

After working with the instructor and gathering materials and information from other experts, developing learning activity packages was begun for each unit of instruction. Each LAP was discussed with the instructor with the input and resourefulness. Tapes and videos materials were selected to accommodate each LAP. Each LAP was also color coded.

Upon completion of six LAPs, two students were selected to examine the LAPs and the video materials and give their evaluations.

In February of 1988, five students helped to field test the LAPs for additions and deletions. This was very beneficial. Immediately it was recognized that shop math had to be taught in order for students to grasp the concepts in the Electricity Concepts I & II course. The student must be proficient in these computational skills: addition, subtraction, multiplication, and division of whole numbers, decimal numbers, and fractions; scientific notation; roots and exponents.

After the completion of the 64 LAPs, a syllabus was written, a quiz for each LAP, study guides and unit tests, and a task/competency profile was written.

In developing a management system to monitor the progress and development of each student, the coordinator and instructor designed classroom space, arranged equipment, developed a filing system, built shelves in classroom for reference books and obtained additional equipment for the Individualized Competence program. The principal books used were the Electricity Concepts Unit I & II Books, machines with self-paced tapes covering each LAP were placed in classroom, and four 13" televisions and VCR'S with headphones were placed in the classroom. With the completion of sixty four LAPs and all equipment and files in place, the Individualized Competency Program began with twenty two students in the Industrial Technology Department in August, 1988.

RESULTS

Through monitoring the self-paced individualized program, the coordinator and instructor discovered that the students set goals and strived to achieve them. Motivational level was higher than in the past traditional teaching of the course. A sense of accomplishment rather than inadequacy and failure was achieved. Students tended to group according to abilities and motivated one another. Other instructors wanted the self-paced program.

Through the implementation of this new teaching strategy, the instructor was able to focus on performance based criteria and students exited the program when competencies were demonstrated.

Further results have been that a model plan has been designed and can be replicated by other departments using basic electricity concepts. Also students did not have to wait for vacancies to occur in the program to provide training opportunities.

Now that the classroom is arranged for self-pacing, all equipment is in place for utilization, and that the training materials have been obtained, the innovative use of facilities has made the program more cost effective.

Lastly, the two overwhelming results have been that no one wanted to drop out of the program and that the job placement has been 94% compared to 45% job placement in related fields in the previous year.

SUMMARY

In summation, the self-paced individualized program can be very beneficial to a student body with a wide range of aptitudes and abilities. The success of the program depends upon the instructor's ability to plan a complete program, identify and acquire quality instructional materials. organize and manage the instructional activities, and evaluate the student's progress.

In order to validate the need for and ascertain the impact of an individualized self-paced instructional program, students must be allowed to participate in an instructional program where the main focus of the program is on performance based criteria, with criterion referenced testing used as a means of determining student competency.

STUDENT EVALUATION
Learning Activity Packages (LAPs)

SCHOOL _____ PROGRAM _____

For each of the following statements, indicate your answer by circling the number corresponding to your response and record any comments.

1. Strongly Disagree 2. Disagree 3. Not Sure 4. Agree 5. Strongly Agree

	Strongly Disagree	Dis-Agree	Not Sure	Agree	Strongly Agree
1. Learning is easier using the Learning Activity Packages (LAPs)	1	2	3	4	5

Comments _____

_____

2. Learning is faster using the LAPs. 1 2 3 4 5

Comments _____

_____

3. The instructor was available for assistance as needed. 1 2 3 4 5

Comments _____

_____

4. Information in the LAPs is arranged in a logical order. 1 2 3 4 5

Comments _____

_____

5. The LAPs are complete. (List any that are not). 1 2 3 4 5

Comments _____

_____

6. The instructions and directions for using the LAPs are clear. 1 2 3 4 5

Comments _____

_____

7. Visual aids (when applicable) made learning easier. 1 2 3 4 5

Comments _____

_____

8. The LAPs are about the right length. 1 2 3 4 5

Comments _____

STUDENT EVALUATION
LAPs

PLEASE ANSWER THE FOLLOWING QUESTIONS:

A. What is the best thing about the Laps? _____

_____

_____

B. What is the worst thing about the Laps? _____

_____

_____

C. What is your overall opinion of the LAPs? _____

_____

_____

D. What error(s) did you discover in the LAPs? _____

_____

_____

ADDITIONAL COMMENTS:

COMPETENCY RECORD

NO.	COMPETENCY	DATE	BY

COURSE SYLLABUS

FOR

ELECTRICITY CONCEPTS I AND II

CROWLEY'S RIDGE VO-TECH SCHOOL

ELECTRICITY CONCEPTS I & II

COURSE DESCRIPTION

This course is for the beginning student in the field of electricity/electronics. It presents an introduction to direct current, and introduction to alternating current, and presents basic mathematical formulas involved in current analysis. Confidence in the construction and analysis of electronic circuity is gained by hands-on exercises throughout the course.

INSTRUCTIONAL MATERIAL

This course utilizes instructor-generated Learning Activity Packets (LAPs). LAPs provide for an individualized self-paced learning environment in which each student progresses through the course at his or her own rate. A majority of the LAPs are slanted toward the Electricity Concepts I and II books. Also, tapes and videos are used with the LAPs.

MAJOR COURSE OBJECTIVES

1. Familiarize students with electricity and electronic terms, components, and circuits.
2. Develop a safe and orderly approach to circuit design and analysis.
3. Acquaint the students with Ohm's Law, Kirchoff's Laws, and the Power Equation.
4. Give the student experience at building series, parallel, and series-parallel circuits.
5. Develop the student's ability to troubleshoot electronic circuits.

6. Introduce the student to the concepts of resistance, voltage, current, and power and show how these parameters affect circuit operation.
7. Explain the properties of induction, capacitance, and magnetism.
8. Give the student hands-on experience with the oscilloscope, digital and analog multimeter, function generators, and various power supplies.

COURSE OUTLINE

FOR

ELECTRICITY CONCEPTS I $ II

LEARNING ACTIVITY PACKET OVERVIEW

Part I. Electricity Concepts I

LAP # 0: Introduction to Electricity Concepts

1. Explain the concept of self-pacing to the student.
2. Acquaint the student with laboratory policies and procedures.

LAP # 1: Laboratory Safety

1. Outline to the student the safety precautions that must be followed while working with or around energized circuits.

LAP #2: Parts and Symbols

1. Introduce the art of circuit design and analysis using breadboard.
2. Develop the student's ability to assemble a circuit using real components from a schematic.

LAP #3: Basic Electricity

1. Define structure of matter, conductors and insulators, and electrical quantities to the student.

LAP #4: Shop Math

1. Offer students practical problem-solving experience in fractions, decimals, roots and powers, formulas and equations, and scientific notation.

LAP #5: Electrical Circuits

1. Present a good background in applying Ohm's Law to solve circuit problems.
2. Provide hands-on experience using digital and analog multimeters to prove Ohm's Law postulates.

LAP #6: Series and Parallel Circuits

1. Introduce series circuits and how to measure voltage, current, and resistance in a series circuit.
2. Introduce parallel circuits and how to measure voltage, current, and resistance in a parallel circuit.
3. Develop the student's ability to analyze circuit faults by following a logical troubleshooting procedure.

LAP #7: Electrical Measurements

1. Acquaint the student with voltage and current measurement and reading meter scales.

LAP #8: Resistance and Resistors

1. Explain the different types of fixed resistors and the construction of adjustable resistors.
2. Introduce the resistor color code as a means of determining a resistor's value in ohm.
3. Give the student hands-on experience using the digital and analog ohmmeter in determining circuit resistances.

LAP #9 Resistive Circuits

1. Enable the student to correctly calculate the total resistance of a number of resistors in series, of resistor combinations, of equal resistors in parallel, of compound resestive circuits.

LAP #10: Thevenin's and Norton's Theorems

1. Present a good background in applying Thevenin and Norton's Theorems to simplify complex circuits.

LAP #11: Electrical Power and Energy

1. Enable the student to correctly define terms, symbols, and units of measurement associated with power.
2. Provide practice in computing the power dissipated by electronic circuits using the power Equation.

3. Give hands-on experience using digital and analog multimeters to measure the circuit parameters required to compute power.

LAP #12: Magenetism

1. Familiarize the student with magnetic poles and fields, temporary and permanent magnets, and magnetic permeability.

LAP #13: Electromagnetism

1. Introduce magnetic fields and current, the solenoid, electromagnetic induction, and electromagnetic induction with current.

LAP #14: Applications of Electromagnetism

1. Introduce the operating principles of electric bells, buzzers, and relays.
2. Provide hands-on experience in the constructing of bells, buzzers, and relays.

PART II Electricity Concepts II

LAP #15: Alternating Current

1. Introduce AC generators, AC waveforms, and the principles of AC transmission.
2. Give the students the necessary mathematical background to calculate frequency, cycle time, and instantaneous AC values (roots and powers).

LAP #16: Inductance

1. Acquaint the student with the property of inductance of coils.
2. Develop the student's ability to design circuits containing specific value of inductance through mathematical analysis.

LAP #17: Capacitance

1. Introduce capacitors, their construction and color code.
2. Develop the student's ability to calculate capacitance from given physical parameters.

LAP #18: Transformers

1. Familiarize the student with terms associated with transformers.
2. Introduce transformer ratios and calculation of primary and secondary voltage, currents, and power.

LAP #19: Motors

1. Introduce the basic operating principles of DC and AC motors.

LAP #20: Generators

1. Introduce the basic operating principles of AC and DC generators.
2. Develop the student's ability to analyze the operation of an AC and a DC generator through complete cycle of operation.

Name _____

ELECTRICITY CONCEPTS

A Learning Activity Packet

Instructional Unit DIRECT CURRENT

LAP Title OHM'S LAW

Performance Objective

After completing the required reading for this LAP, you will be able to state Ohm's Law, use Ohm's Law to solve problems, and use Ohm's Law with circuit measurements. This knowledge will be evidenced by completing the assignment sheets with no errors on each assignment sheet, and you will score 100% on the quiz. Also, your completion of the job sheet will be assessed by your instructor, and you will score 90% or more on the Unit Test.

Tasks

1. Demonstrate the ability to use Ohm's Law with circuit measurements.
   - A. Construct a circuit on the breadboard.
   - B. Use the multimeter to measure the voltage across each of the two resistors within ± 1 volt.
   - C. Calculate the current through each resistor.
   - D. Use multimeter to measure current through each resistor within ± 1 amp.

REFERENCES:

A. Zbar, Paul B. Basic Electricity, 5th ed., New York: McGraw-Hill Book Co., 1983.

B. Floyd, Thomas L. Electric Circuits, Columbus: Charles E. Merrill Publishing Company, 1983.

LAP#	Prerequisites	Time Range (Hours)	Date Started	Date Completed
5.2	LAP #5.1	7		

LEARNING STEPS

Place a check to the left of each step after completion.

_____ 1.	READ:	Performance Objective and Tasks, page 1.
_____ 2.	READ:	Unit Objective and Specific Objectives, page 2-1.
_____ 3.	VIEW:	The video tape "Ohm's Law," tape #5.2.
_____ 4.	READ:	Information Sheet #1, pgs. 4-14.
_____ 5.	DO:	Assignments Sheets #1 and #2, pages 15-16.
_____ 6.	DO:	Assignment Sheets #3 and #4, pages 17-18.
_____ 7.	CHECK:	Your answers to the Assignment Sheets with the Answers to Assignment Sheets, pg. 19. If you missed more than 2 problems on each assignment sheet, restudy this LAP and see your instructor for additional help.
_____ 8.	CHECK:	With your instructor for the quiz.
_____ 9.	DO:	Job Sheet #1, pg. 20.
_____ 10.	CHECK:	Job Sheet #1 with the instructor. Be prepared to answer any question the instructor may have concerning this job sheet.
_____ 11.	TAKE:	The Unit Test.
_____ 12.	IF:	A score of 90% or more is attained on the Unit Test, continue on to the next LAP as outlined in the curriculum guide.

OR

If less than 90% was scored on the Unit Test, restudy this LAP and see the instructor for additional help. Retake the Unit Test. Once a score of 90% or more is attained, continue on to the next LAP as outlined in the curriculum guide.

OHM'S LAW

UNIT OBJECTIVE

After completing the required reading for this LAP, you will be able to state Ohm's Law, use Ohm's Law to solve problems, and use Ohm's Law with circuit measurements. This knowledge will be evidenced by completing the assignment sheets with no errors on each assignment sheet, and you will score 100% on the quiz. Also, your completion of the job sheet will be assessed by your instructor, and you will score 90% or more on the Unit Test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. State Ohm's Law
2. Draw the circular expression of Ohm's Law
3. List three uses of Ohm's Law
4. Solve problems for an unknown voltage.
5. Solve problems for an unknown current.
6. Solve problems for an unknown resistance.
7. Demonstrate the ability to use Ohm's Law with circuit measurements.

This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets, by completing the assignment sheets with no errors, by scoring at least 90% on the Unit Test.

INFORMATION SHEET #1

Ohm's Law

Since the existence of an electrical potential causes current to flow in a circuit, and as this current is opposed by resistance, a relationship must exist between current, voltage, and resistance. In the early part of the 19th century George Simon Ohm proved by experiment that a precise relationship exists between current, voltage, and resistance. This relationship is called Ohm's Law and is stated as follows:

LAW 1. THE CURRENT IN A CIRCUIT IS DIRECTLY PROPORTIONAL TO THE APPLIED VOLTAGE AND INVERSELY PROPORTIONAL TO THE CIRCUIT RESISTANCE.

Ohm's Law may be expressed as an equation:

$$I = \frac{E}{R}$$

Where: I = current in amperes

E = voltage in volts

R = resistance in ohms

If any two of the quantities in the Ohm's Law equation are known, the thrid may be easily found. For example, Figure 1 shows a circuit containing a resistance of 1.5 ohms and a source voltage of 1.5 volts. How much current flows in the circuit?

Given: E = 1.5 volts

R = 1.5 ohms

I = ?

Solution:

$$I = \frac{E}{R}$$

$$I = \frac{1.5}{1.5}$$

$$I = 1 \text{ amp.}$$

To observe the effect of source voltage on circuit current, the above problem will be solved again using double the previous source voltage.

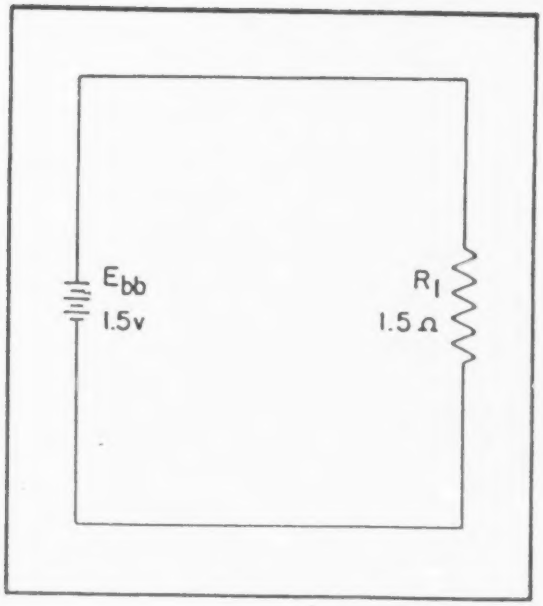


Figure 1. Determining current in a basic circuit.

Given: E = 3 volts

R = 1.5 ohms

I = ?

Solution:

$$I = \frac{E}{R}$$

$$I = \frac{3}{1.5}$$

I = 2 amps

Notice that as the source voltage doubles, the circuit current also doubles. Circuit current is directly proportional to applied voltage and will change by the same factor that the voltage changes.

To verify the statement that current is inversely proportional to resistance, assume the resistor in Figure 1 to have a value of 3 ohms.

Given: $E = 1.5$ volts

$R = 3$ ohms

$I = ?$

Solution:

$$I = \frac{E}{R}$$

$$I = \frac{1.5}{3}$$

$I = 0.5$ amp

Comparing this current of 0.5 amp for the 3 ohm resistor, to the 1 amp of current obtained with the 1.5 ohm resistor, shows that doubling the resistance will reduce the current to one-half the original value. Circuit current is inversely proportional to the circuit resistance.

In many circuit applications current is known and either the voltage or the resistance will be the unknown quantity. To solve a problem in which current and resistance are known, the basic formula for Ohm's Law must be transposed to solve for E as follows:

Basic equation: $I = \frac{E}{R}$

Multiply both sides of the equation by R.

$$IR = \frac{E}{R} R$$

$$IR = E$$

$$E = IR$$

To transpose the basic formula when resistance is unknown:

Basic equation: $I = \frac{E}{R}$

Multiply both sides of the equation by R.

$$IR = \frac{E}{R} R$$

$$IR = E$$

Divide both sides of the equation by I.

$$\frac{IR}{I} = \frac{E}{I}$$

Example: What voltage is required to properly light a lamp having a resistance of 10 ohms and a current rating of 1 ampere?

First draw a circuit like Figure 2 including all the given information.

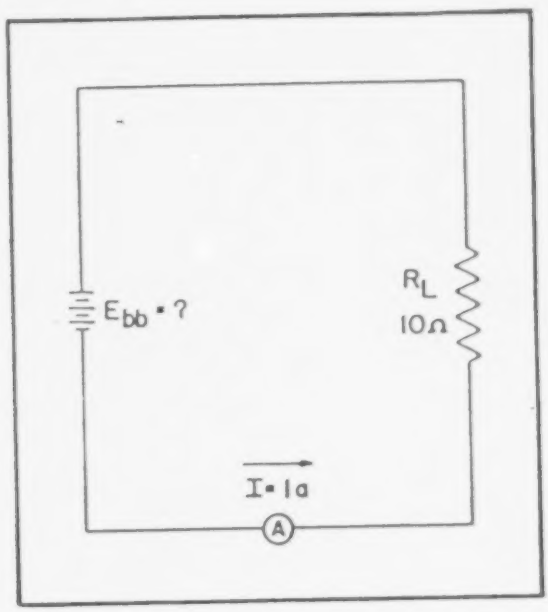


Figure 2: Determining voltage in a basic circuit.

Given: R = 10 ohms

I = 1 ampere

E = ?

Solution: E = IR

E = 1 x 10

E = 10 volts

Example: When a 10 volt source is connected to a circuit, the circuit draws 5 amperes of current from the source. How much resistance is contained in the circuit?

Given: E = 10 volts

I = 5 amperes

R = ?

Draw and label circuit (Figure 3).

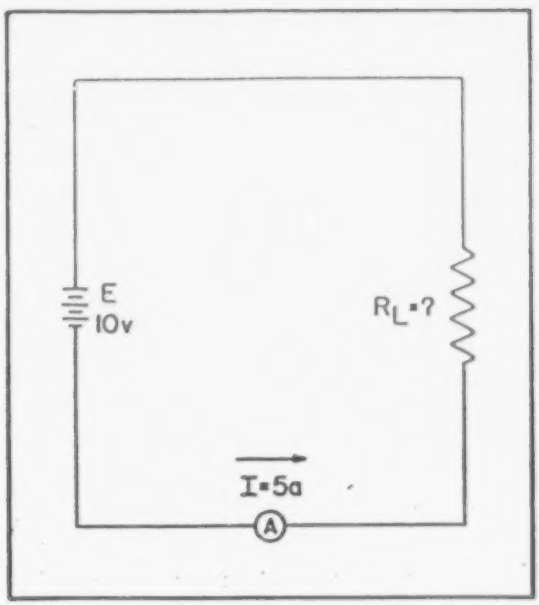


Figure 3 - Determining resistance in a basic circuit.

Solution:

$$R = \frac{E}{I}$$

$$R = \frac{10}{5}$$

R = 2 ohms

Although the three equations representing Ohm's Law are fairly simple, they are perhaps the most important of all electrical equations. These three equations and the law they represent MUST be THOROUGHLY UNDERSTOOD before continuing on to more advanced theory.

Graphical Analysis

One of the most valuable methods of inquiry available to the technician is that of graphical analysis. No other method provides a more convenient or more rapid way to observe the characteristics of an electrical device.

The first step in constructing a graph consists of obtaining a table of data from which the graph will evolve. The information in the table can be obtained experimentally by taking laboratory measurements on the device under examination, or can be obtained theoretically through a series of computations. The latter method will be used here.

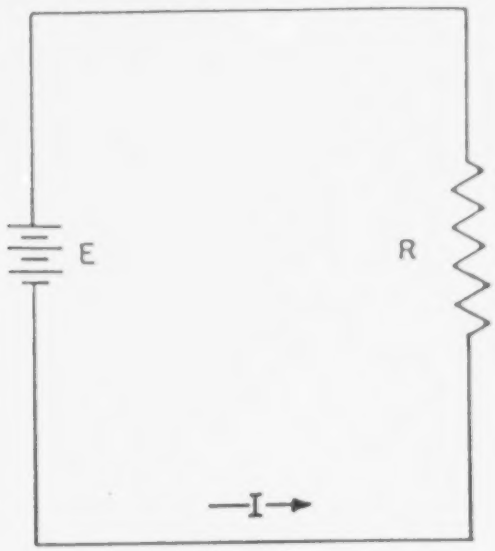


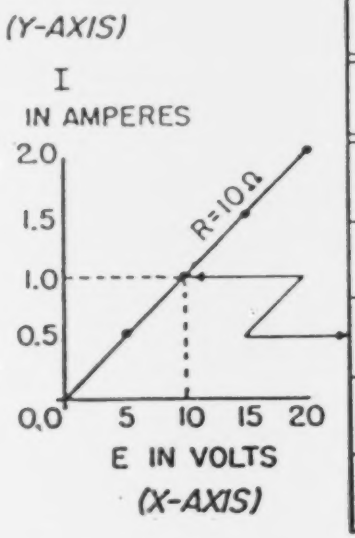
Figure 4

Let us assume that the characteristics of the circuit shown in Figure 4 are to be investigated using Ohm's Law and graphical methods. Since there are three variables (E, I, and R) under consideration, there are three unique graphs that may be constructed.

In constructing any graph of electrical quantities, it is standard practice to vary one quantity in a specified way, and note the changes which occur in a second quantity. The quantitiy which is intentionally varied is called the independent variable and is plotted on the X-Axis. The second quantity which changes as a result of changes in the first quantity is called the dependent variable and is plotted on the Y-Axis. Any other quantities involved are held constant.

In the circuit of Figure 4 the resistance will remain fixed (constant) and the voltage (independent variable) will be varied. The resulting changes in current (dependent variable) will then be graphed.

To aid in compiling the data, a table of values is completed as shown in Figure 5. This table shows R to be held constant at 10 ohms as E is varied from 0 to 20 volts in 5-volt steps. Through the use of Ohm's Law the value of current in column two of the table can be calculated for each value of voltage in column one. When the table is complete, the information it contains can be used to construct the graph in Figure 5. For example, when the voltage applied to the 10-ohm resistor is 10 volts, the current is 1 ampere. These values of current and voltage determine a point on the graph. When all the points have been plotted, a smooth curve is drawn through the points. This curve is called the volt-ampere characteristic for the 10-ohm resistor.



R=10Ω	
E	I
0	0.0
5	0.5
10	1.0
15	1.5
20	2.0

Figure 5 - Volt ampere characteristic.

Through the use of this curve the value of current through the resistor can be quickly determined for any value of voltage between 0 and 20 volts.

A very important characteristic of a fixed resistor is illustrated by the graph in Figure 5. Since the volt-ampere characteristic curve is a straight line, it shows that equal changes of voltage across a resistor produce equal changes in current through the resistor. Because of this straight line characteristic, the fixed resistor is called a linear device.

This graph illustrates an important characteristic of the basic law — namely, the current varies directly with the applied voltage if the resistance is constant.

If the voltage across a load is maintained at a constant value, the current through the load will depend solely upon the effective resistance of the load. For example, with a constant voltage of 12 volts and a resistance of 12 ohms, the current will be 12/12, or 1 ampere. If the resistance is halved, the current will be doubled; if the resistance is doubled, the current will be halved. In other words, the current will vary inversely with the resistance.

If the resistance of the load is reduced in steps of 2 ohms starting at 12 ohms and continuing to 2 ohms, the current through the load becomes 12/10 = 1.2 amperes; 12/8 = 1.5 amperes; 12/6 = 2 amperes and so forth. The relation between current and resistance in this example is expressed as a graph (Figure 6), whose equation is I = 12/R. The numerator of the fraction represents a constant value of 12 volts in this example. As R approaches a small value the current approaches a very large value. The example illustrates a second equally important relation in Ohm's law -- namely, that the current varies inversely with the resistance.

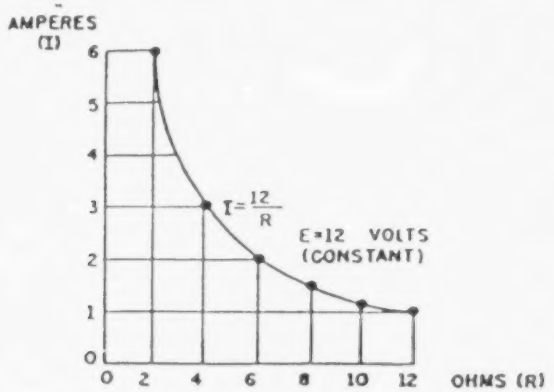


Figure 6 - Relation between current and resistance.

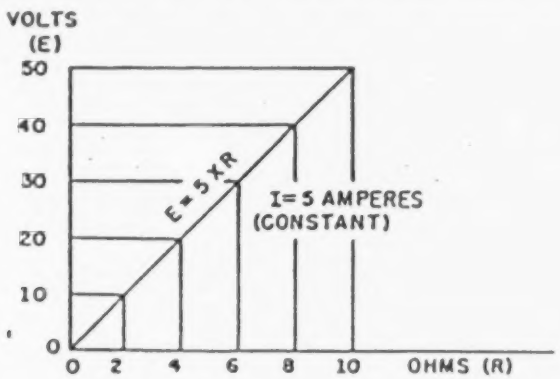


Figure 7 - Graph of voltage vs. resistance with constant current.

If the current through the load is maintained constant at 5 amperes, the voltage across the load will depend upon the resistance of the load and will vary directly with it. The relation between voltage and resistance is shown in Figure 7. Values of resistance are plotted horizontally along the X-Axis to the right or the origin, and corresponding values of voltage are plotted vertically along the Y-Axis above the origin. The graph is a straight line having the equation E = 5R. The coefficient 5 represents the assumed current of 5 amperes which is constant in this example. Thus, a third important relation is illustrated -- namely, that the voltage across a device varies directly with the effective resistance of the device provided the current through the device is maintained constant.

Applying Ohm's Law

The equation I = E/R may be transposed to solve for the resistance if the current and voltage are known, or to solve for the voltage if the current and resistance are known. Thus, R = E/I and E = IR. For example, if the voltage across a device is 50 volts and the current through it is 2 amperes, the resistance of the device will be 50/2, or 25 ohms. Also if the current through a wire is 3 amperes and the resistance of the wire is 0.5 ohm, the voltage drop across the wire will be 3 x 0.5, or 1.5 volts.

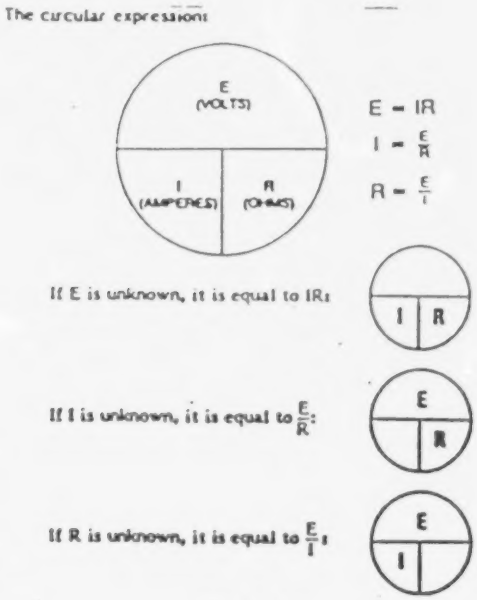


Figure 8

Equation I = E/R and its transpositions may be obtained readily with the aid of Figure 8. The circle containing E, I, and R is divided into two parts with E above the line and IR below it. To determine the unknown quantity, first cover that quantity with a finger. The location of the remaining uncovered letters in the circle will indicate the mathematical operation to be performed. For example, to find I, cover I with a finger. The uncovered letters indicate the E is to be divided by R, or I - E/R. To find E, cover E. The result indicates that I is to be multiplied by R, or E = IR. To find R, cover R. The result indicates that E is to be divided by I, or R = E/I.

Another Remembering Tool

The "Eagle - Indian - Rabbit" Illustration

Figure 9

When in doubt look at the Ohm's Law circle and replace the standard symbols with those shown in Figure 9. An eagle, indian and rabbit. Remember the usual location of these three and then plug in the given parameters and calculate the missing number.

Example to find R = the Rabbit sees Eagle in air, over Indian $R = E/I$

find I = the Indian sees Eagle in air, over Rabbit $I = E/R$

find E = Eagle sees Rabbit and Indian on ground $E = I \times R$

The beginning student is cautioned not to rely wholly on the use of these diagrams when tranposing simple formulas but rather to use them to supplement his knowledge of the algeraic method. Algebra is a basic tool in the solution of electrical problems and the importance of knowing how to use it should not be underemphasizded or bypassed after the student has learned a shortcut method such as the one indicated in these figures.

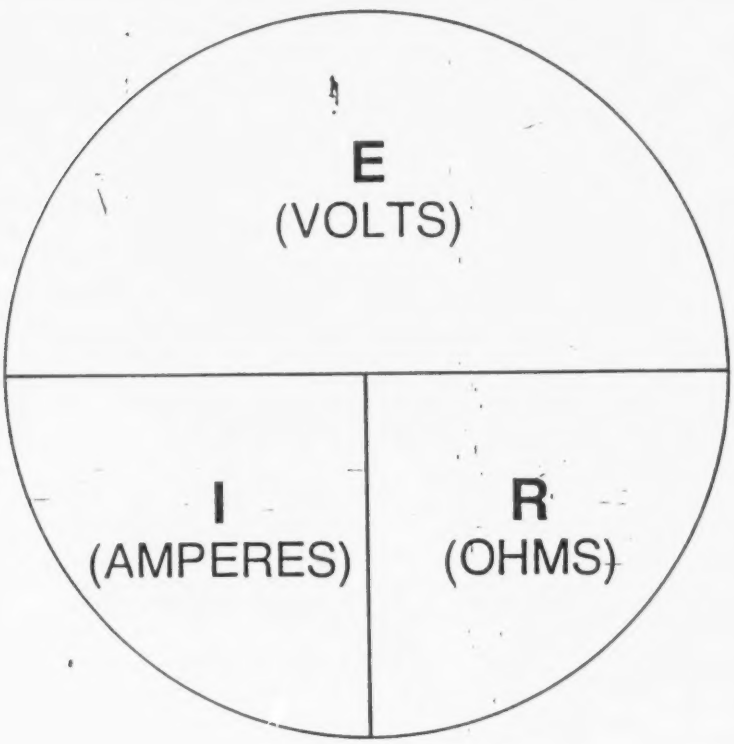
Ohm's Law

One volt is required to push one amp through one ohm resis tance.

$$E = IR$$

Volts = Amperes x Ohms

Ohm's Law Magic Circle

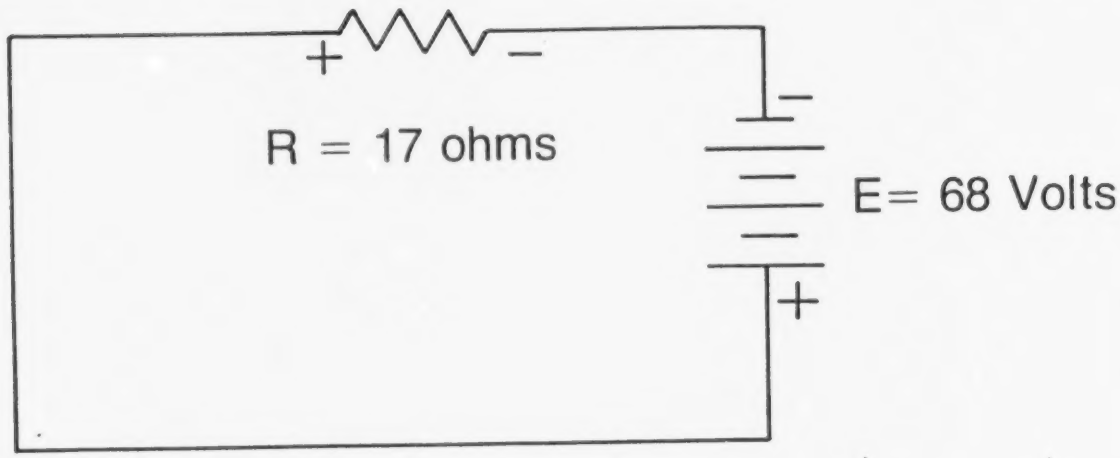


$$E = IR$$

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

Ohm's Law--Computing Current

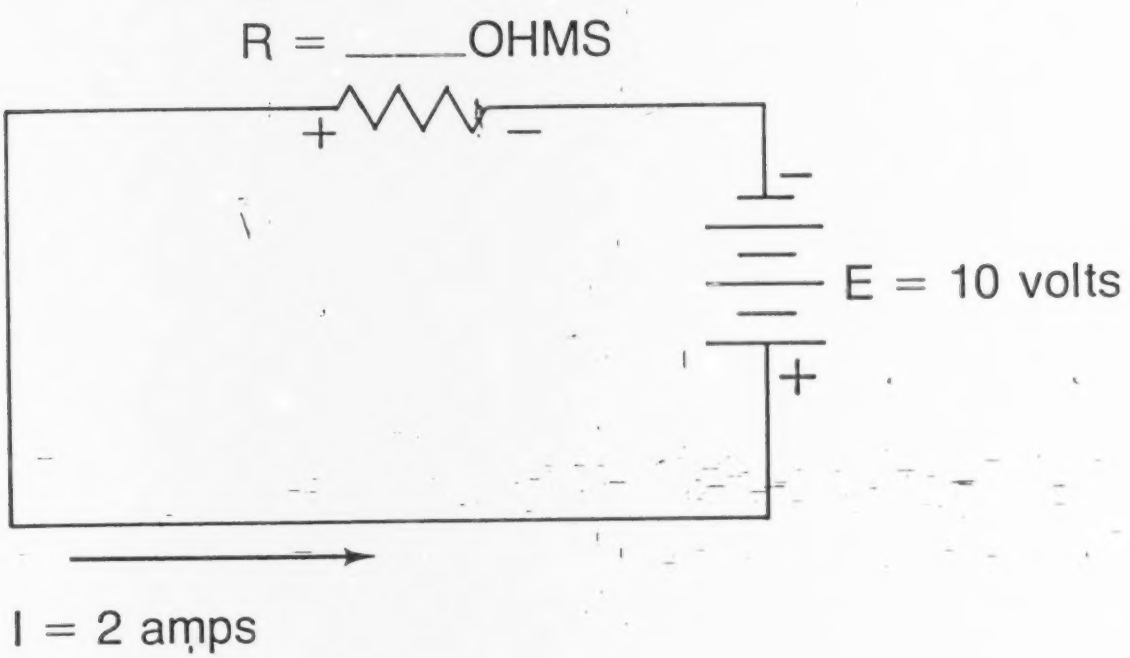


I = ____ amps

How many amperes of current are flowing in this circuit?

$E = IR$ $\qquad I = \frac{E}{R}$ $\qquad I = \frac{68 \text{ volts}}{17 \text{ ohms}} = 4 \text{ amperes}$

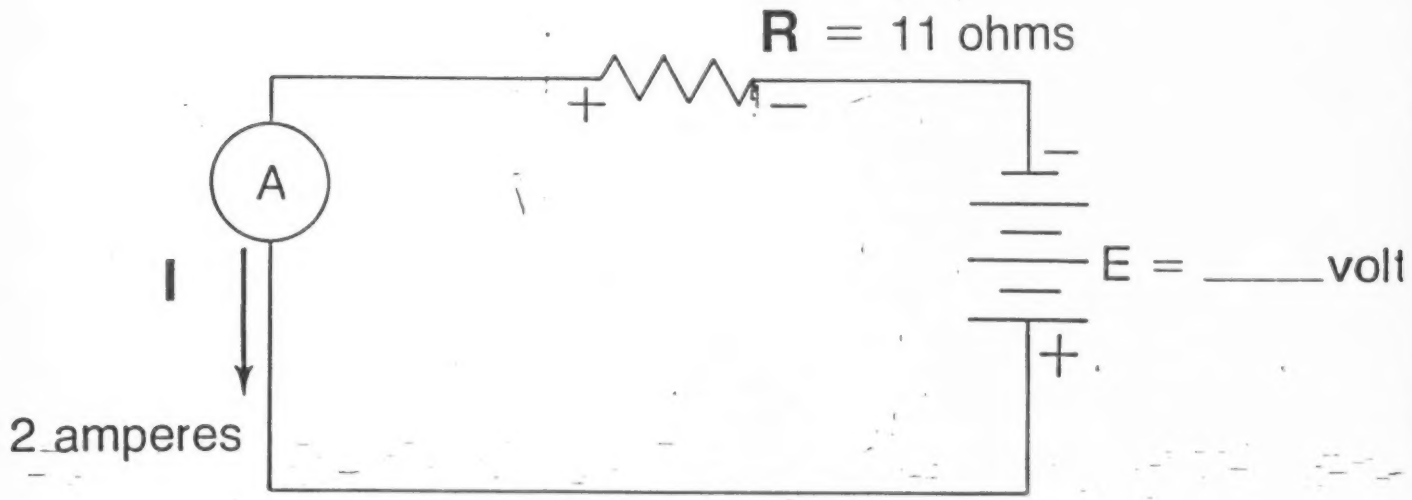
Ohm's Law--Computing Resistance



What is the resistance value of the resistor in this circuit?

$E = IR$ $\qquad R = \frac{E}{I}$ $\qquad R = \frac{10 \text{ volts}}{2 \text{ amperes}} = 5 \text{ ohms}$

Ohm's Law--Computing Voltage



What voltage is being supplied by the battery?

E = IR E = 2 amperes x 11 ohms, E = 22 volts

The value of the voltage being supplied by the battery is 22.

SUMMARY

The relationship of voltage, current, and resistance is described by Ohm's Law, which is basic to all circuits. Current in a circuit is directly proportional to the applied voltage and inversely proportional to the circuit resistance.

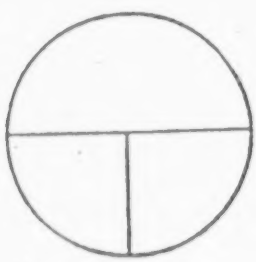
ASSIGNMENT SHEET I

BASIC OHM'S LAW KNOWLEDGE

Match the definitions and phrases on the left to the terms on the right:

_____1. EMF	A. Volt
_____2. Amp	B. Ohm
_____3. Unit of voltage	C. Ampere
_____4. Unit of electrical current	D. Direct proportion
_____5. Increase in quantity causes decrease in another	E. Inverse proportion
_____6. Decrease in quantity causes decrease in another	
_____7. Decrease in quantity causes increase in another	
_____8. Unit of resistance	

9./10./11. Fill in the missing symbols in the circle (E, I, R):



ASSIGNMENT SHEET II

SOLVE PROBLEMS FOR AN UNKNOWN RESISTANCE

Directions: Apply the appropriate formula to find resistance.

Example: 440 volts, 10 amps = _____ ohms

Answer: R = E/I = 440/10 = 44 ohms

Problems:

	Volts	Amps	Ohms
1.	240	4	____
2.	24	9.6	____
3.	12	5	____
4.	230	5	____
5.	24	8	____
6.	24,	2 m	____
7.	12	3μ	____
8.	1 K	5 m	____
9.	1×10^3	0.5×10^3	____
10.	2.5×10^3	5×10^3	____

ASSIGNMENT SHEET III

SOLVE PROBLEMS FOR AN UNKNOWN CURRENT

Directions: Apply the appropriate formula to find the current in the following problems.

Example: 120 volts, 40 ohms = _____ amps

Answer: I = E/R = 120/40 = 3 amps

Problems:

	Volts	Ohms	Amps
1.	240	12	____
2.	110	11	____
3.	440	20	____
4.	120	30	____
5.	24	3	____
6.	12	1	____
7.	5×10^{-6}	1	____
8.	2×10^{-3}	4×10^{-3}	____
9.	20 K	$5 \times 10^{+6}$	____
10.	1 K	0.5×10^{6}	____

ASSIGNMENT SHEET IV

SOLVE PROBLEMS FOR AN UNKNOWN VOLTAGE

Directions: Apply the appropriate formula from Ohm's Law to find the voltage in the following problems:

Example: 2 amps, 60 ohms = _____ volts

Answer: E = IR = 2 x 60 = 120 volts

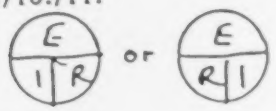
Problems:

	Amps	Ohms	Volts
1.	20	6	_____
2.	4	60	_____
3.	9.6	2.5	_____
4.	5	3	_____
5.	75.	0.16	_____
6.	2×10^{-3}	5×10^{3}	_____
7.	1×10^{-6}	10×10^{3}	_____
8.	8μ	1M	_____
9.	2m	2K	_____
10.	1	1	_____

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet I:

1. A
2. C
3. A.
4. C
5. E.
6. D
7. E
8. B
9./10./11.



Assignment Sheet II:

1. 60
2. 2.5
3. 2.4
4. 46
5. 3
6. 12K
7. 4M
8. 200K
9. 2
10. 500Ω

Assignment Sheet III:

1. 20
2. 10
3. 22
4. 4
5. 8
6. 12
7. 5 μ
8. 500Ω
9. 4m
10. 2m

Assignment Sheet IV:

1. 120
2. 240
3. 24
4. 15
5. 12
6. 10
7. 10m
8. 8
9. 4
10. 1

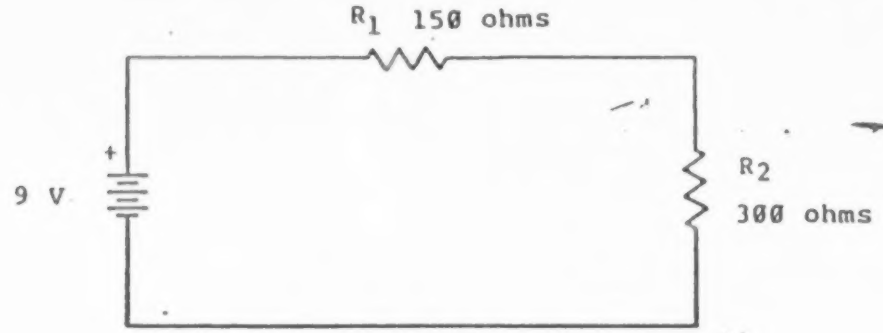
JOB SHEET #1

A. Tools and Materials:

1. 1 150 ohm resistor
2. 1 300 ohm resistor
3. Tektronix PS503A Power Supply
4. Tektronix DM501A or DM502A Digital Multimeter
5. Protoboard breadboard, test leads and cables

B. Procedure:

1. Construct the following circuit on the breadboard:



2. Using the multimeter, adjust the power supply for exactly 9.0 volts, then measure the voltage across each of the two resistors.

V_{R1} = _____

V_{R2} = _____

Given the value of each resistor and the voltage across each, calculate the current through each.

I_{R1} = _____

I_{R2} = _____

3. Use the multimeter to measure the current through each of the resistors and record the measurement below.

I_{R1} = _____

I_{R2} = _____

CHECK WITH YOUR INSTRUCTOR